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described above can significantly broaden the domain of practical application of nonlinear CAD methods.

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References

1 NAKHLA, M. S., and VLACH, J.: 'A piecewise harmonic-balance technique for determination of periodic response of nonlinear systems', *IEEE Trans.*, 1976, CAS-23, pp. 85–91

2 RIZZOLI, V., CECCHETTI, C., LIPPARINI, A., and MASTRI, F.: 'General-purpose harmonic-balance analysis of nonlinear microwave circuits under multitone excitation', *IEEE Trans.*, 1988, MTT-36, pp. 1650–1660

3 ZEIN, D. A.: 'Solution of a set of nonlinear algebraic equations for general purpose CAD programs', *in* RUEHLI, A. E. (Ed.): 'Circuit analysis, simulation and design' (North Holland, 1986), pp. 207–279

4 YEAGER, H. R., and DUTTON, R. W.: 'Improvement in norm-reducing Newton methods for circuit simulation', *IEEE Trans.*, 1989, CAD-8, pp. 538–546

5 BANKS, R. E., and ROSE, D. J.: 'Global approximate Newton methods', *Numer. Math.*, 1981, 37, pp. 279–295

6 RIZZOLI, V., MASTRI, F., and CECCHETTI, C.: 'A highly efficient p–n junction model for use in harmonic-balance simulation'. Proc. 19th European Microwave Conf., London, 1989, pp. 979–984

NOVEL DOUBLY SELF-ALIGNED AlGaAs/GaAs HBT

Indexing terms: Bipolar devices, Semiconductor devices and materials, Transistors

A novel, doubly self-aligned process technology for AlGaAs/GaAs heterojunction bipolar transistors (HBT) has been developed. This doubly self-aligned process enables self-alignment for all emitter, base, and collector contacts and the fabricated device occupies an area approaching the intrinsic device area. The resulting base–collector capacitance of a fabricated device is reduced below half of the base–collector capacitance of conventional devices. The reductions in the capacitance are reflected in the superior cutoff frequency and maximum oscillation frequency of the doubly self-aligned devices as compared with conventional devices.

Heterojunction bipolar transistors (HBTs) are promising for both microwave and digital switching applications and laser drivers in optoelectronic ICs.[1] One of the most important parameters of HBTs is the base–collector capacitance, C_{bc}. From a circuit standpoint, it is desirable to decrease the base–collector capacitance, even though the base resistance may be increased.[2] This letter presents the device structure, processing description and preliminary high frequency characteristics of a new doubly self-aligned HBT aimed at decreasing this capacitance. In this doubly self-aligned process, both the base and the collector are self-aligned to the emitter through the use of a two-emitter-mesa geometry. Consequently, the base–collector capacitance is reduced in two ways in the doubly self-aligned HBT as compared to conventional devices. In conventional devices, any base–collector misalignment requires a nonzero spacing, L_x, between the collector and the base contacts. This spacing contributes to an additional parasitic capacitance to the intrinsic C_{bc}. With the present process, the need for this additional spacing is eliminated and C_{bc} is thus reduced to a minimum. In addition, the use of the two-emitter-mesa geometry shrinks the device width to half that of the conventional device, while maintaining the same transconductance.[2] Therefore, C_{bc} is reduced as the overall device area is halved.

The epitaxial layer structure of the doubly self-aligned HBT was grown by molecular beam epitaxy, and includes: a 6000 Å subcollector, a 3500 Å n^- collector at $5 \times 10^{16}/cm^3$, a 900 Å p^+ base at $1 \times 10^{19}/cm^3$, a 900 Å n^- emitter at $5 \times 10^{17}/cm^3$. The emitter consists of three regions; a 300 Å thick layer parabolically graded between the base and the centre of the emitter with the Al mole fraction, x, graded from $x = 0$ to $x = 0{\cdot}3$, a centre 300 Å region with $x = 0{\cdot}3$, and a final 300 Å thick layer linearly graded from $x = 0{\cdot}3$ to $x = 0$. On top of this emitter region is a 600 Å thick InGaAs contact layer to facilitate non-alloyed ohmic contact. A 100 Å undoped spacer layer is inserted between the emitter and the base to prevent Be diffusion from the base into the emitter.

The schematic cross-sectional view of a doubly self-aligned HBT is shown in Fig. 1. The process begins with a dual

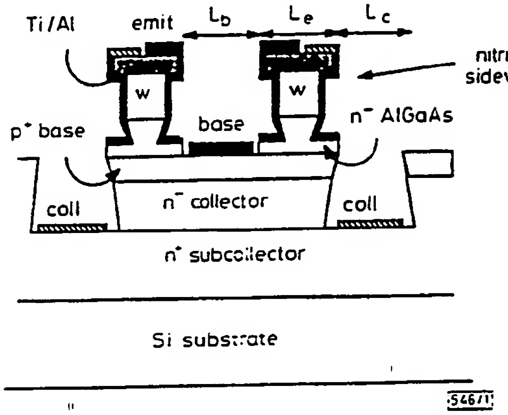

Fig. 1 *Doubly self-aligned HBT structure with base between two emitter-mesas*

proton implant to define the active device area. Next, a layer of W is sputter deposited on the entire surface. A Ti/Al metal layer is evaporated and then selectively lifted-off using the emitter mask. The metal emitter contacts are subsequently used as a natural mask to permit the removal of the unwanted W by reactive ion etching (RIE) with C_2F_6 and SF_6. The emitter contacts are again used as a mask to wet-etch the regions other than the emitter mesas down to approximately 700 Å above the p^+ base layer. The depleted AlGaAs pr tection ledges, thus formed, have demonstrated suppression of surface recombination.[3] A layer of silicon nitride is then deposited by plasma enhanced chemical vapour deposition (PECVD). This nitride is then etched with RIE, leaving only sidewall nitride covering the sides of the emitter mesas.

Next, the base photolithography is performed. The alignment of the base to the emitter is not critical because of the two-emitter-mesa geometry employed in in the process. As shown in Fig. 1, L_b denotes the base contact length, and L_e, the emitter contact length. The base length on the mask is designed by $L_b + L_e$ so that even with a misalignment of $1/2L_e$, the base metal of length L_b falls on the base region as desired. The extra base metal of length L_e is distributed on the top of the two emitter mesas. Following the base lithograhy, wet etching is used to etch down to the p^+ base. A non-alloyed base metal of Ti/Pt/Au is evaporated and lifted-off. Similarly, the collector is self-aligned to the emitter. The collector length on the collector mask is designed to be $L_c + L_e$, allowing for a misalignment of $1/2L_e$. The only difference is that the defined collector region is wet-etched to the n^+ subcollector and an alloyed Au/Ge/Ni/Au contact is used to contact the collector.

One consequence of the doubly self-aligned process is the ease of interchanging the base and collector masks since both masks are self-aligned to the emitter. The structure of Fig. 2 results when the masks are interchanged. This structure has the advantage that the collector is fabricated prior to the base contact. Consequently, proton bombardment underneath the base contacts, which can be used to reduce the base–collector capacitance, can be performed without any possibility of the

alloying of collector contact at high temperatures.

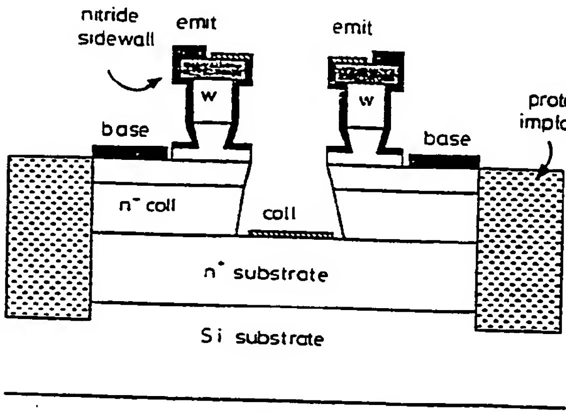

Fig. 2 *Doubly self-aligned HBT device with base and collector contacts interchanged*

The transistor characteristics have been measured. Devices of both structures in Fig. 1 and Fig. 2 demonstrate similar DC characteristics. Fig. 3 shows the common emitter characteristics of a typical HBT device with $L_e \times W_e = 3 \times 10\,\mu m^2$. The small signal current gain at low current is 40, and a maximum current gain of 55 is obtained at a collector current density of $2{\cdot}5 \times 10^4\,A/cm^2$ with a breakdown voltage of 8 V and an offset voltage of 0·3 V. The ideality factor for the collector current in a Gummel plot approaches 1·1, and the ideality factor for the base current ranges between 1·4 and 1·6. Preliminary high frequency performances of the devices have also been measured. Fig. 4 shows the cutoff frequency, f_T, and the maximum oscillation frequency, f_{max}, of device structures of Figs. 1 and 2 as a function of collector current. All devices shown have $L_e = 2\,\mu m$ and a total emitter area of $16\,\mu m^2$. The base length L_b is also $2\,\mu m$. Conventional devices with $L_e \times W_e = 2 \times 8\,\mu m^2$ and L_x of $3\,\mu m$ were fabricated on the same wafer for comparison. Both f_T and f_{max} of the conventional devices are lower than the high frequency performance of the structures in Figs. 1 and 2 throughout the current range shown. The highest f_T for the conventional device is 23 GHz and the highest f_{max} is 28 GHz.

In conclusion, we have demonstrated a novel doubly self-aligned HBT technology. This doubly self-aligned process enables self-alignment for all emitter, base, and collector contacts. The fabricated device thus occupies an area approaching the intrinsic device area, without extra area necessary for misalignment tolerances. In addition, by using the two-emitter-mesa geometry, this process shrinks the device width to half that of the conventional device while maintaining the same transconductance. The reductions in the parasitics are reflected in the superior cutoff frequency and maximum oscillation frequency of the doubly self-aligned devices.

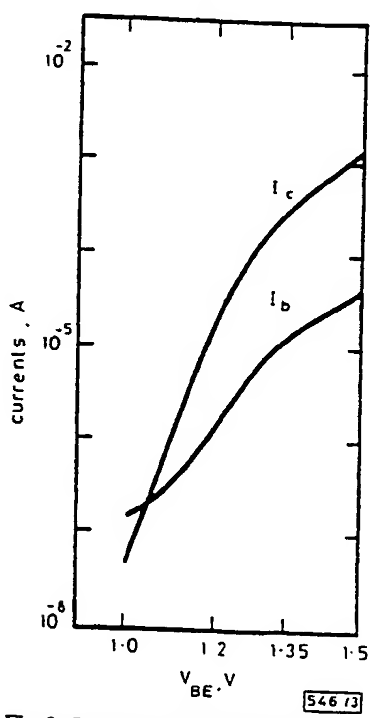

Fig. 3 *Gummel plot of typical device*

$V_{ce} = 2{\cdot}5$ V

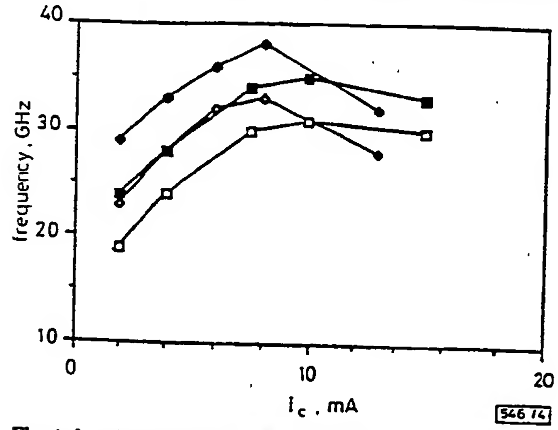

Fig. 4 *f_T and f_{max} against collector current*

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References

1 YAMAUCHI, Y., NAGATA, K., NAKAJIMA, O., ITO, H., NITTONO, T., and ISHIBASHI, T.: '22 GHz 1–4 frequency divider using AlGaAs/GaAs HBTs', *Electron. Lett.*, 1987, 23, pp. 881–882

2 MADIHIAN, M., HONJO, K., HIDEO, T., and KUMASHIRO, S.: 'The design, fabrication, and characterization of a novel electrode structure self-aligned HBT with a cutoff frequency of 45 GHz', *IEEE Trans.*, 1987, ED-34, p. 1419

3 LEE, W. S., UEDA, D., MA, T., PAO, Y. C., and HARRIS, J. S.: 'Effect of emitter–base spacing on the current of AlGaAs/GaAs heterojunction bipolar transistors', *IEEE Electron Device Lett.*, 1989, EDL-10, pp. 200–202

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HIERARCHICAL MEAN-RESIDUAL IMAGE VECTOR QUANTISER USING GRADIENT-LAPLACIAN SUBSPACE DISTORTION

p. 1362–1364

Indexing terms: Image processing

A new hierarchical mean-residual image vector quantiser (HMRIVQ) using a general 4-dimensional gradient-Laplacian subspace distortion (GLSD) is proposed. With the use of the GLSD the computational and storage costs of the encoder are significantly reduced. The HMRIVQ can also achieve a very high compression rate for low detailed images.

Introduction: Vector quantisation (VQ) has been successfully applied to both speech and image coding.[1–3] Currently most of the image VQ techniques have been used small and fixed block size throughout the coding process. The compression rate is therefore limited to between 8 and 16. In order to tackle this problem, Vaisey and Gersho[4] proposed a variable

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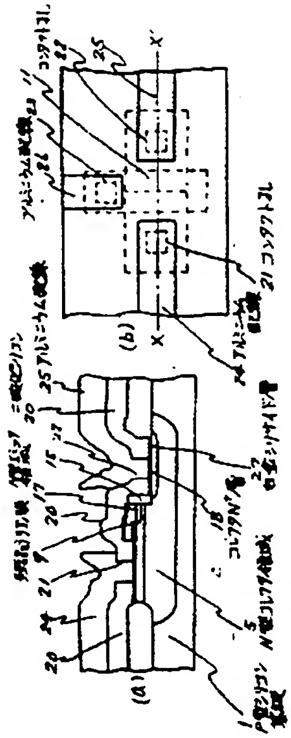

ABSTRACT : PURPOSE: To reduce sharply a collector resistance by connecting a metal wiring leading out a collector region into a substrate surface with an insulation formed in an end side of a polycrystalling silicon film through a low resistance collector layer formed by self-registration.

CONSTITUTION: A polycrystalline silicon layer 9 contacts directly a substrate surface of an overlapping region in a collector led-out region side, and it contacts through a thin insulating film 4 in a base led-out region side, an emitter region 17 is formed in a base region from a contacting face in the collector led-out region side. In the collector led-out region, a recessed portion which is shallower than the substrate surface and the collector region and is deeper than the base region is formed, and a collector surface 18 is exposed in a recessed portion bottom, and a recessed portion side is covered with an insulating film 15. Electrodes 26, 24 and 25 of emitter, base and collector are led-out respectively from a polycrustalline silicon layer 9, a base led-out region surface and the recessed portion bottom 18.

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